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14. ABSTRACT
The project developed a novel Lagrangian particle/panel method for geophysical fluid flow on a rotating sphere. The method is potentially relevant to Naval operations that rely on accurate and efficient modeling of atmosphere and ocean dynamics. The award supported Peter Bosler in the final stage of his Ph.D. thesis which he successfully completed in May 2013.

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Final Technical Report

ONR Award Number: N00014-12-1-0509
Title: Particle Methods for Atmosphere and Ocean Modeling
PI: Robert Krasny, University of Michigan

Summary

The award supported Peter Bosler in the final stage of his Ph.D. thesis which he successfully completed in May 2013 [1]. Dr. Bosler was co-supervised by Professor Robert Krasny in the Mathematics Department and Professor Christiane Jablonowski in the Department of Atmospheric, Oceanic and Space Sciences. Dr. Bosler is currently a Postdoctoral Assistant Professor in the Mathematics Department with 50% support from ONR Award N00014-14-1-0075.

The project developed a novel Lagrangian particle/panel method (LPPM) for geophysical fluid flow on a rotating sphere. The method is potentially relevant to Naval operations that rely on accurate and efficient modeling of atmosphere and ocean dynamics.

The dynamical cores in current use for geophysical fluid flow employ Eulerian mesh-based methods to solve the momentum equation. By contrast, the LPPM approach tracks the Lagrangian flow map and uses a discrete form of the Biot-Savart integral to compute the velocity from the vorticity. The flow map is represented by particles and panels, and each particle carries vorticity with magnitude changing dynamically due to the Coriolis effect.

In his thesis Dr. Bosler developed new remeshing and refinement techniques to maintain accuracy as the particles become disordered by the flow. He applied the method to solve the barotropic vorticity equation for several examples including Rossby-Haurwitz waves, Gaussian vortices, and a perturbed zonal jet. His results demonstrate the capability of the LPPM method in resolving small-scale features in the vorticity. An article on this work has been submitted for publication [2]. Two other articles stemming from his thesis are in preparation, one on the polar vortex [3], and another on passive tracer advection [4]. Movies can be viewed on Dr. Bosler's website [5].

Dr. Bosler is now extending the Lagrangian particle/panel method to solve the shallow water equations. In this case the particles carry height and divergence in addition to vorticity. The approach requires solving two Poisson equations, one for the vorticity and stream function, and another for the divergence and velocity potential function. Preliminary results are promising and we believe the goal is within reach.

Presentations

- Bosler attended the NCAR workshop, "Transport Schemes on the Sphere", March 30-31, 2011, where he gave a talk. He is a co-author on an article describing the workshop results [6].

- Bosler presented a poster at the SIAM Annual Meeting, Minneapolis, July 9-13, 2012.

- Bosler gave a contributed talk at the "PDEs on the Sphere" conference, Cambridge, England, September 24-28, 2012.
- Bosler gave an invited talk in the minisymposium, "Numerical Methods for Transport", at the SIAM CSE Conference, Boston, February 25-March 1, 2013.
- Krasny presented Bosler's work at the IUTAM Symposium on "Vortex Dynamics", March 10-14, 2013, Fukuoka, Japan.
- Bosler gave a contributed talk at the annual meeting of the American Physical Society Division of Fluid Dynamics, Pittsburgh, November 24-26, 2013.

References

[1] P.A. Bosler (2013) Particle Methods for Geophysical Flow on the Sphere, Ph.D. Thesis, University of Michigan

[2] P. Bosler, L. Wang, C. Jablonowski, R. Krasny, A Lagrangian particle/panel method for the barotropic vorticity equation on a rotating sphere, submitted to Fluid Dynamics Research

[3] P. Bosler, C. Jablonowski, R. Krasny, Simulation of polar vortex dynamics due to sudden stratospheric warming, in preparation

[4] P. Bosler, C. Jablonowski, R. Krasny, Passive tracer advection computed by a Lagrangian particle/panel method

[5] P. Bosler, `http://www-personal.umich.edu/~pbosler/research/sphere-movies`

[6] P.H. Lauritzen, P.A. Ullrich, C. Jablonowski, P. Bosler, D. Calhoun, A.J. Conley, T. Enomoto, L. Dong, S. Dubey, O. Guba, A.B. Hansen, E. Kaas, J. Kent, J.-F. LaMarque, M.J. Prather, D. Reinert, W.C. Skamarock, B. Sorensen, M.A. Taylor, J.B. White III, A standard test suite for two-dimensional linear transport on the sphere: Results from a collection of state-of-the-art schemes. to appear in Geoscientific Model Development Discussions